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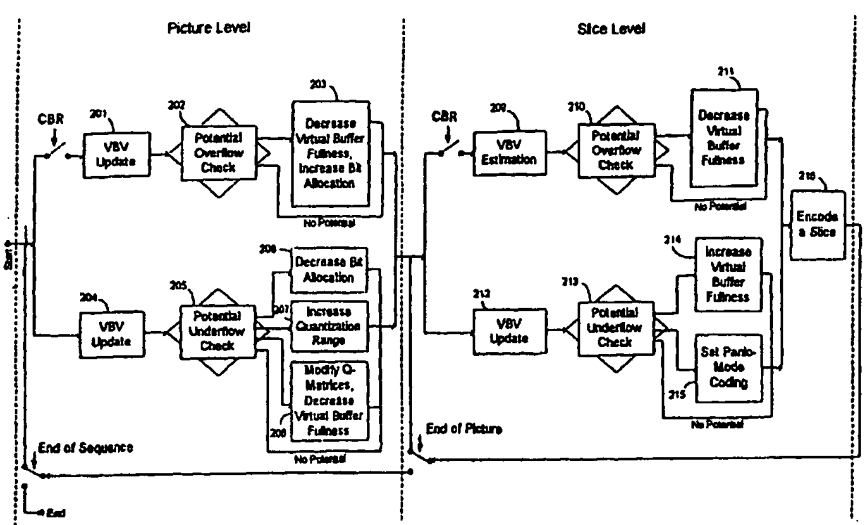
(54) **Title:** METHOD AND APPARATUS FOR VIDEO BUFFER VERIFIER UNDERFLOW AND OVERFLOW CONTROL



(57) **Abstract:** A method and apparatus for Video Buffer Verifier (VBV) underflow and overflow control. A combination of picture and slice level control is used in the method and apparatus. Improved prevention of overflow and panic mode encoding is achieved by means of adjustment of the virtual buffer-fullness which allows the quantization-step to have an improved response to the buffer-fullness at both high and low critical levels. The use of a non-linear quantization scheme and customised quantization matrices also provide improved prevention of panic mode encoding. The slice level control also reduces the computation complexity compared to the macroblock level control.

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Method And Apparatus For Video Buffer Verifier Underflow And Overflow Control

Technical Field

The present invention relates to Video Buffer Verifier (VBV) control of a video encoder, and in particular, to the efficient prevention of VBV underflow and overflow during MPEG-2 video encoding.

Background Art

VBV constraints in MPEG-2

The MPEG-2 coded bitstreams are required to meet the constraints imposed by the Video Buffer Verifier (VBV). The VBV is provided with an input buffer known as the VBV buffer which is conceptually used to simulate the entering and removing of coded data to and from a decoder's buffer.

Typically, constraints are imposed which require the entering and removing of the coded data so that the VBV buffer does not overflow or underflow. These constraints are used to guarantee that the decoder buffer will not overflow or underflow.

A virtual VBV buffer is maintained in the encoder and its buffer-fullness is updated to emulate the buffer-fullness in the decoder (refer to figure 1). Buffer overflow arises when a picture consumes too few bits while the decoder is nearly full. The bits which arrive at the decoder during the next picture period

will then cause an overflow. Note that this overflow constraint applies only to the constant bit-rate application. Buffer underflow occurs when a picture generates too many bits. The constraints of underflow and overflow are considered separately.

VBV buffer-fullness, $VBV\_fullness_t$, where t is the picture period, is updated after encoding one picture as follows:

$$VBV\_fullness_t = VBV\_fullness_t - S \qquad (1)$$

where S is the number of bits used for the encoded picture.

At this point, the MPEG-2 underflow constraint states that after the above buffer-fullness update, the buffer-fullness shall not be less than zero:

$$VBV\_fullness_t >= 0 \qquad (2)$$

The VBV buffer is then filled with the average number of bits per picture, *Bpp*, which is *Bit_rate* divided by *frame_rate* (for variable bit-rate operation, the maximum bit-rate is used to calculate *Bpp*):

$$VBV\_fullness_{t+1} = VBV\_fullness_t + Bpp \qquad (3)$$

and at this point, the overflow constraint specifies that for a constant bit-rate operation the VBV buffer shall not be greater than the VBV buffer size:

$$VBV\_fullness_{t+1} <= VBV\_buffer\_size \qquad (4)$$

Details of the VBV specifications can be found in Annex C of the Recommendation ITU-T H.262 (ISO 13818-2 MPEG-2) the disclosures of which are herein incorporated by reference.

MPEG2 TM-5 rate control

In the MPEG-2 Test Model-5 (TM-5) of an MPEG-2 video encoder, "virtual buffer-fullness", is used to determine the reference quantization parameter. Before encoding macroblock j (j>=1), the fullness of the appropriate virtual buffer is computed:

$$d_j^i = d_0^i + B_j - 1 - T_i(j-1) / MB\_cnt$$

or

$$d_j^p = d_0^p + B_j - 1 - T_p(j-1) / MB\_cnt$$

or

$$d_j^b = d_0^b + B_j - 1 - T_b(j-1) / MB\_cnt$$

depending on the picture type,

where,

d_0^i, d_0^p, d_0^b are initial fullness of virtual buffers - one for each picture type;

B_j is the number of bits generated by encoding all macroblocks in the picture, up to and including j;

MB_cnt is the number of macroblocks in the picture; and

d_j^i, d_j^p, d_j^b are the fullness of virtual buffers at macroblock j - one for each picture type.

The final fullness of the virtual buffer (d_j^i, d_j^p, d_j^b: j=MB_cnt) is used as d_0^i, d_0^p, d_0^b for encoding the next picture of the same type.

The reference quantization parameter Q_j for macroblock j is then computed as follows:

$$Q_j = (d_j * 31) / r$$

where the "reaction parameter" r is given by

$$r = 2 * bit\_rate / picture\_rate$$

and d_j is the fullness of the appropriate virtual buffer.
The initial value for the virtual buffer-fullness is:

$$d_0^i = 10 * r/31$$
$$d_0^p = K_p\, d_0^i$$
$$d_0^b = K_b\, d_0^i$$

where K_p and K_b are "universal" constants dependent on the quantization matrices.

VBV control

It is to be noted that the following prior art relating to VBV buffer overflow and underflow control algorithm descriptions are typically performed prior to encoding a picture, and after the VBV buffer-fullness rises by *Bpp*.

Underflow control

In typical VBV underflow control, such as that disclosed in US Patent No. 5,650,860, two levels of control are performed. First, the picture level, and then, the macroblock level.

To control buffer underflow in picture level, the target bit *T* for the next picture is adjusted when necessary such that it does not lead to underflow:

$$VBV\_fullness - T >= 0 \qquad (5)$$

In addition to the picture-level preventing of buffer underflow, macroblock (MB) level control is utilised by means of defining a level above the

"VBV_fullness=0" level named the "panic level". If the VBV_fullness should fall below this level, then the encoder will enter "panic mode". In this mode, only the minimum amount of data to maintain the integrity of the bitstream will be transmitted. In the panic mode all DCT coefficients and all motion vectors are set to zero, thereby generating a minimal amount of conforming encoded data.

To detect this panic level, macroblock (MB) level updating of VBV buffer-fullness is therefore required. The VBV_fullness is updated after encoding each MB:

$$VBV\_fullness = VBV\_fullness - S_{mb} \tag{6a}$$

$$if\ (\ VBV\_fullness < panic\text{-}level)\ \text{-----}>\ Enter\ Panic\ mode\ coding \tag{6b}$$

where S_{mb} is the number of bits used to encode the macroblock. The encoder will enter the panic mode coding when VBV buffer-fullness is less than panic level.

Overflow control

As disclosed in US Patent No. 5,650,860, to avoid VBV overflow, adding zero "stuffing bits" to the bitstream is utilised, when VBV overflow occurs after encoding a picture. However, instead of simply stuffing bits to the bitstream which is considered a waste, the encoder may first determine, prior to encoding a picture, if there are "extra bits", and add a value *extra_bits* to the target bits, *T*, to increase the bits used for the current picture that is to be encoded, which is given by:

$$extra\_bits = VBV\_fullness - T + Bpp - VBV\_buffer\_size \tag{7}$$

$$If\ (extra\_bits > 0)\ then \quad T = T + extra\_bits \tag{8}$$

After encoding the current picture, only the necessary number of filling bits are added to the bitstream.

It has been found that the picture-level overflow control is unable to prevent VBV buffer overflow effectively when a sequence switched from a high level of motion (having lots of scene-changes) to a low level of motion. One of the reasons is that the assumption used in equation (7) is not true most of the time.

Equation (7) assumes that the bits used for coding the current picture is equal to the target bits allocated T to forecast the amount of *extra_bits* required. This assumption is generally not true which is why the prediction of overflow at picture level is quite poor.

Another reason is that the quantization-step which is quite high during a “fast” sequence does not “react” or reduce fast enough when there is a sudden change to a “slow” sequence, therefore generating insufficient bits and causing the VBV buffer to overflow.

If a sequence of pictures are to difficult to encode at a given bit-rate (for example due to a very noisy and action-packed sequence or a synthetic sequence with lots of scene-changes coded at a low bit-rate), when even the maximum quantization-step is used and still could not be sustained at the given low bit-rate, the VBV buffer will reach the panic level.

The prior art prevention method of adjusting the target bits allocation T at picture level is not able to control bits in the VBV buffer when encoding a difficult sequence at a low bit-rate. Using the target bits allocated T to judge the potential of underflow is also not effective.

In panic mode encoding all DCT coefficients are set to zero, the intra-coded macroblocks will appear as "grey-level" blocks subsequently followed by B and P pictures which could be quite irritating, subjectively, to a user.

This identifies a need for a new type of Video Buffer Verifier (VBV) control of a video encoder which overcomes the problems inherent in the prior art.

Disclosure Of Invention

In a preferred embodiment, the present invention seeks to provide improved prevention of panic mode encoding, improved underflow and overflow prevention, and improved quality of video. This is sought to be achieved by implementing additional picture and slice level controls which include:

1) Virtual buffer fullness control (d_0);

2) Quantization-step range control (linear/non-linear quantization); and/or

3) Optional quantization matrices modification.

As macroblock level control is generally required in the panic mode detection and this control has higher implementation costs, it is also sought to be provided by the present invention that the complexity of VBV control is reduced by using slice level control instead of MB level control.

The present invention further seeks to provide a method for Video Buffer Verifier (VBV) control of a video encoder, whereby picture and/or slice level controls are implemented in the method, said picture and/or slice level controls including:

virtual buffer fullness control for increasing the sensitivity of a Q-step; and/or

quantization-step range control for increasing the range of the Q-step.

The present invention also seeks to provide a method wherein, the method additionally includes quantization matrices modification for the prevention of panic mode coding.

Preferably, slice level control is used in place of an MB level control.

In a broad form, the present invention provides that the method results in improved prevention of an underflow or an overflow.

In a further broad form, the present invention provides that the method results in improved encoding at a low bit-rate.

Preferably, the video encoding is MPEG-2 video encoding.

The present invention according to one aspect seeks to provide a method which includes the following steps:

at the picture level control:

updating the VBV buffer-fullness in at least one VBV Update module before at least one Potential Overflow Check module;

reducing the virtual buffer-fullness and increasing the target bit allocation in a Decrease Virtual Buffer-Fullness and Increase Bit Allocation module;

if there is an underflow potential, then according to that underflow potential level: reducing a target bit T in a Decrease Bit Allocation module; increasing quantization range in an Increase Quantization Range module; and/or modifying the quantization matrices and reducing the virtual buffer-fullness in a Modify Q-Matrices and Decrease Virtual Buffer-Fullness module;

at the slice level control:

estimating the VBV buffer-fullness in a VBV Estimation module;

checking for an overflow potential in a Potential Overflow Check module;

if an overflow potential is found, decreasing the virtual buffer-fullness in a Decrease Virtual Buffer-Fullness module;

for underflow control, updating the slice level VBV in a VBV Update module;

performing a potential underflow check in a Potential Underflow Check module;

after determination of the underflow potential level: increasing the virtual buffer-fullness in an Increase Virtual Buffer-Fullness module; and/or setting the panic mode coding in a Set Panic Mode Coding module; and

encoding a slice in an Encode a Slice module.

In a further broad form of the present invention, the present invention also seeks to provide that the method assists in panic mode coding prevention by addition of a preventive margin to a target bits factor *T*.

In another preferred form of the invention it is sought to provide that a variable panic level may be used.

The present invention according to another aspect seeks to provide a method wherein, for constant bit-rate coding:

at the picture level:

overflow prediction is rendered more sensitive by incorporating a factor dependent on the encoding bit-rate; and

reducing the virtual buffer-fullness when a factor *extra-bits* is greater than 0;

at the slice level:

estimating the VBV buffer-fullness in each slice and reducing the virtual buffer-fullness if required.

Also preferably, specified levels of buffer-fullness are experimentally determined for each picture type.

In a specific embodiment of the present invention, values of *Th1, Th2 and Th3* are 200 000, 150 000 and 100 000 respectively for a PAL picture.

In a further embodiment of the present invention there is provided an apparatus for Video Buffer Verifier (VBV) control of a video encoder, whereby the apparatus contains integrated picture and/or slice level controls, said picture and/or slice level controls including:

a virtual buffer-fullness control for increasing the sensitivity of a Q-step; and/or

a quantization-step range control for increasing the range of the Q-step.

Broadly, the apparatus additionally includes quantization matrices modification for the prevention of panic mode coding.

In accordance with a specific embodiment of the present invention there is provided apparatus which at the picture level includes:

at least one VBV Update module;

at least one Potential Overflow Check module;

a Decrease Virtual Buffer Fullness and Increase Bit Allocation module;

a Decrease Bit Allocation module;

an Increase Quantization Range module; and

a Modify Q-Matrices and Decrease Virtual Buffer-Fullness module;

and at the slice level said apparatus includes:

a VBV Estimation module;

a VBV Update module;

a Potential Overflow Check module;

a Potential Underflow Check module;

a Decrease Virtual Buffer-Fullness module;

an Increase Virtual Buffer-Fullness module;

a Set Panic Mode Coding module; and

an Encode a Slice module.

In another preferred form of the invention there is provided a method for Video Buffer Verifier (VBV) control of a video encoder, substantially according to the

method described in the specification with reference to the accompanying figures.

In another preferred form of the invention there is provided an apparatus for Video Buffer Verifier (VBV) control of a video encoder, substantially according to the embodiment described in the specification with reference to and as illustrated in the accompanying figures.

Brief Description Of Figures

The present invention will become apparent from the following description, which is given by way of example only, of a preferred but non-limiting embodiment thereof, described in connection with the accompanying figures, wherein:

- Figure 1 illustrates a preferred embodiment of the present invention wherein, the figure shows an illustration of how a VBV buffer is updated.

- Figure 2 illustrates a preferred embodiment of the present invention wherein, the figure shows a block diagram illustrating picture and slice level VBV control.

- Figure 3 illustrates a preferred embodiment of the present invention wherein, the figure shows a detailed flow diagram the picture and slice level VBV buffer underflow and overflow control.

Modes For Carrying Out The Invention

In a particular embodiment, the present invention is directed to the prevention of VBV underflow and overflow during MPEG-2 video encoding.

Underflow control

Picture level:

The basic step in underflow and panic mode coding prevention is the reducing of the target bits T when necessary. The target bits T in equation (5) are replaced by $(T+PM)$ where PM is defined as the preventive margin to take care of the additional bits that might be used to encode the next picture.

Apart from adjusting the target bits T, additional picture level prevention steps can be used.

A further preventive step is to increase the range of the quantization-step (Q-step) to be used, for example the MPEG-2 non-linear quantization scheme allows the quantization-step to go up to 112. This is used when a potential of panic mode occurrence is detected.

A still further preventive step which may be optionally employed is to use customised quantization matrices which are of higher values than the default Q matrix, when a higher potential of panic mode encoding is detected.

Slice level:

Instead of using the MB level of updating and checking panic level encoding, slice level is used to reduce computation requirements and the potential of panic mode coding of individual MB.

Slice level underflow control for panic mode detection and prevention is performed after encoding each slice of a picture. A Variable Panic Level (VPL) may be used. The VPL varies according to the number of remaining slices (j) to be coded. The slice panic level is made variable depending on the remaining

number of slices yet to be encoded to further optimise the VBV control such that the encoder does not go into the panic mode prematurely.

In addition, a slice level adjustment of the virtual buffer-fullness, d_0, (described hereinbefore and in the rate-control of MPEG-2 TM-5) is performed when necessary. When there is a potential of panic mode encoding, the value of d_0 (one for each picture-type) is increased to ensure that the quantization-step (which is computed based on the value of d_j) can reach the maximum value in a shorter time interval.

Overflow Control (for constant bitrate coding only)

Picture level:

As hereinbefore discussed, the picture level overflow prediction described in equations (7) and (8) is not effective. To render the prediction more sensitive, the value of T in equation (8) is replaced by a value P which depends on the encoding bit-rate of the encoder.

In addition, the virtual buffer fullness d_0 is reduced when *extra_bits* in equation (8) is greater than 0, in an attempt to reduce the Q-step more rapidly during the encoding of next picture.

Slice level:

The VBV buffer-fullness is estimated in each slice to check if the VBV buffer is going to be filled up, and d_0 is further reduced if necessary.

More Detailed Description

A preferred, but non-limiting, embodiment of the present invention is shown in figure 2. This figure shows the block diagram of the apparatus in accordance

with the picture and slice level VBV control of the present invention. Note that overflow control is generally only carried out for constant bit-rate encoding.

At the picture level control, the VBV buffer-fullness is updated in the VBV Update modules 201 and 204 before the potential overflow and underflow check modules 202 and 205 respectively.

The virtual buffer-fullness d_0 is reduced and the target bit allocation is increased in module 203 if there is an overflow potential. If there is an underflow potential, according to the underflow potential level, one or more actions including reducing target bit T (module 206); increasing quantization range (module 207); and modifying the quantization matrices and reducing the virtual buffer fullness (module 208) are carried out.

At slice level (a row of MB), the VBV buffer-fullness is estimated in module 209. If an overflow potential is found in module 210, virtual buffer-fullness d_0 is decreased in module 211. For underflow control, the slice level VBV update is performed in module 212 and the potential underflow check is performed in module 213.

Depending on the underflow potential level, actions are taken in module 214 to increase the virtual buffer fullness d_0 and in module 215 to set the panic mode coding.

Figure 3 shows an example of the detailed flow diagram of the picture and slice level underflow and overflow control. The rate control in module 217 is a rate control which uses the virtual buffer-fullness d_j for determination of quantization-step, such as in the MPEG-2 TM-5.

Picture level control:

For picture level overflow control, before encoding each picture, possible *extra_bits* is computed in module 320 and checked in module 321 as to whether the target bits T need to be increased in module 322:

$$extra\_bits = VBV\_fullness - P + Bpp - VBV\_buffer\_size \qquad (9)$$

The value of P is set depending on the encoding bit-rate, for example, 1/4*Bpp.

If the target bits are required to be increased by *extra_bits*, which indicates that the VBV buffer is about to overflow, the value of d_0 is reduced by a value $d2$ in module 324 if it is found to be greater than $dhigh/2$ in module 323. This is to allow the Q-step to reduce fast enough when an overflow is likely in a situation such as sudden changes in motion activities from very fast to very slow.

In picture level underflow control, the target bits T is first adjusted if necessary in module 326:

$$if\ (\ (T+PM) > VBV\_fullness)\ then \quad T = VBV\_fullness - PM \qquad (10)$$

Setting a small PM value might not be enough to take care of the bits-used discrepancy, and setting a high PM might cause "over-reaction" or unnecessary adjustment in target bit T. The value of PM used is typically experimentally determined, for example a value equal to Bpp is often found to be suitable.

If a sequence of pictures are to difficult to encode at a given bit-rate, when even the maximum quantization-step (Qmax=62 for MPEG-2 linear quantization scheme) is used and still could not be sustained at the given low bit-rate, the VBV buffer will reach the panic level.

To prevent this from happening, the non-linear quantization (NLQ) scheme which allows the Q value to reach a higher maximum value (Qmax_non_linear=112 in MPEG-2) is used (module 328). The decision of

when to use NLQ (module 327) can be made by means of checking if the VBV buffer-fullness reaches a specified low level, *Th1*:

if (VBV_fullness < Th1) -----> use non-linear quantization scheme
else ------> *use* linear quantization scheme

Or, by means of checking whether the average Q-step of the picture has reached its maximum:

if (Qmean >= Qmax_linear) -----> use non-linear quantization scheme
else ------> use linear quantization scheme

If using this NLQ is still not enough to cause the buffer-fullness to drop further, the optional customised inter and intra quantization matrix (which have larger values than the default Q-matrix) are then used in an effort to prevent the buffer fullness level from entering the panic level. The decision of when to use the customised Q-matrix (CQM) in module 329 can be made by means of checking if the buffer-fullness reaches an even lower level at *Th2*:

if (VBV_fullness < Th2) -----> use customised inter & intra Q-matrices
else -----> use default Q-matrices

Or, by means of checking whether the average non-linear Q-step of the picture has reach its maximum:

if (Qmean==Qmax_non_linear) ----> use customised inter & intra Q-matrices
else -----> use default Q-matrices

When switching from the default Q-matrix to the customised Q-matrix (module 333), the value of d_0 is reduced in module 334 by a value *d2* to allow the Q-steps to have some room for adjustment.

In a preferred embodiment of the present invention, the values of *Th1, Th2* and *Th3* are experimentally determined as 200 000, 150 000 and 100 000 respectively for PAL picture. The optional customised Q-matrices are scaled versions of the default Q-matrices. The scaling factor used is 1.25 for Intra-Q-matrix and 1.5 for Inter-Q-matrix. It should be appreciated that these values may be varied if desired.

Slice level control:

To ensure that no overflow bits are wastefully stuffed, slice level VBV buffer-fullness estimation is performed. Before encoding the current picture, the estimated_VBV_fullness is first initialised in module 319. After encoding each slice, the estimated_VBV_fullness is updated in module 303:

$$estimated\_VBV\_fullness = estimated\_VBV\_fullness - S_{slice} + B_{ps} \qquad (11a)$$

where S_{slice} is the number of bits used to encode the slice and B_{ps} is the average number of bits per slice (*Bpp / number_of_slice_per_picture*). The value d_0 is further reduced in module 305 at slice level if it is found in module 304 that the estimated_VBV_fullness exceeds the buffer size, *VBV_buffer_size*, so as to further increase the bits used in encoding the next slice.

$$if\ (estimated\_VBV\_fullness > VBV\_buffer\_size)\quad d_0 = d_0 - d1 \qquad (11b)$$

For underflow control, the estimated VBV buffer-fullness is updated in module 306:

$$VBV\_fullness = VBV\_fullness - S_{slice} \qquad (12)$$

where S_{slice} is the number of bits used to encode the current slice. Note that S_{slice} includes the bits used for encoding the picture header for the first slice. If the

VBV buffer-fullness is found in module 307 to be lower than threshold *Th3*, the value of d_0 is increased in module 309 by a value *d2* to ensure that the quantization-step can reach the maximum value quicker, if it is found in module 308 that it has not reach its upper limit *dhigh*.

A variable panic level (VPL) which is defined as:

$$VPL = j*Slice\_max\_panic + Slice\_max\_nonpanic \qquad (13)$$

is computed in module 310. The VPL varies according to the number of remaining slices, *j*, to be coded. The *Slice_max_panic* is the maximum number of bits required to encode a slice in the panic mode and the *Slice_max_nonpanic* is the maximum number of bits required to encode a slice in the non-panic mode but at the maximum quantization-step.

The slice panic level is made variable depending on the remaining number of slices yet to be encoded to make the VBV control more optimal such that the encoder does not go into the panic mode prematurely. A panic mode encoding flag is set in module 312 as an indication to the encoder, if it is found in module 311 that the VBV_fullness goes below the VPL.

The values of *d1, d2* and *dhigh* are experimentally determined and suitable values are 50 000, 100 000 and 500 000 respectively.

The values of *Slice_max_nonpanic* and *Slice_max_panic* are chosen carefully to guarantee that no underflow will occur. The values are experimentally determined and may vary according to the picture type and picture size. An example value for *Slice_max_nonpanic* is 10 000, and example values for *Slice_max_panic* are 2000 for I-picture and 150 for P and B pictures.

After the picture is encoded, *bits_stuff* is computed in module 314 and checked in module 315, if there are bits-stuffing module 316 is required. Rate control

and bit-allocation is then performed in module 317 and the VBV buffer-fullness is then updated in module 318.

The preferred embodiment of the present invention performs well in terms of picture quality and buffer-fullness control. The additional picture and slice level overflow and underflow control provide improvements over the prior art, especially in terms of panic mode prevention and overflow prevention. Panic mode encoding has been avoided even for very difficult sequence coding at very low bit-rate. Slice level underflow control is used in place of MB level control and the complexity requirements are reduced as well as individual MB panic mode coding avoided.

VBV buffer overflow is also avoided when encoding video sequences which switch from a high level of motion (having lots of scene-changes) to a low level of motion, which demonstrates that the quantization-step is able to respond quickly enough to the changes.

Thus, there has been provided in accordance with the present invention, a Video Buffer Verifier (VBV) control of a video encoder which satisfies the advantages set forth above.

The invention may also be said broadly to consist in the parts, elements and features referred to or indicated in the specification of the application, individually or collectively, in any or all combinations of two or more of said parts, elements or features, and where specific integers are mentioned herein which have known equivalents in the art to which the invention relates, such known equivalents are deemed to be incorporated herein as if individually set forth.

Although the preferred embodiment has been described in detail, it should be understood that various changes, substitutions, and alterations can be made

herein by one of ordinary skill in the art without departing from the scope of the present invention as hereinbefore described and as hereinafter claimed.

The claims defining the invention are as follows:

1. A method for Video Buffer Verifier (VBV) control of a video encoder, whereby picture and/or slice level controls are implemented in the method, said picture and/or slice level controls including:

virtual buffer fullness control for increasing the sensitivity of a Q-step; and/or

quantization-step range control for increasing the range of the Q-step.

2. A method as claimed in claim 1 wherein, the method additionally includes quantization matrices modification for the prevention of panic mode coding.

3. A method as claimed in either claim 1 or claim 2 wherein, the slice level control is used in place of an MB level control.

4. A method as claimed in any one of the claims 1 to 3 wherein, the method results in improved prevention of an underflow or an overflow.

5. A method as claimed in any one of the claims 1 to 4 wherein, the method results in improved encoding at a low bit-rate.

6. A method as claimed in any one of the claims 1 to 5 wherein, the video encoding is MPEG-2 video encoding.

7. A method as claimed in any one of the claims 1 to 6 wherein, said method includes the following steps:

at the picture level control:

updating the VBV buffer-fullness in at least one VBV Update module before at least one Potential Overflow Check module;

reducing the virtual buffer-fullness and increasing the target bit allocation in a Decrease Virtual Buffer-Fullness and Increase Bit Allocation module;

if there is an underflow potential, then according to that underflow potential level: reducing a target bit T in a Decrease Bit Allocation module; increasing quantization range in an Increase Quantization Range module; and/or modifying the quantization matrices and reducing the virtual buffer-fullness in a Modify Q-Matrices and Decrease Virtual Buffer-Fullness module;

at the slice level control:

estimating the VBV buffer-fullness in a VBV Estimation module;

checking for an overflow potential in a Potential Overflow Check module;

if an overflow potential is found, decreasing the virtual buffer-fullness in a Decrease Virtual Buffer-Fullness module;

for underflow control, updating the slice level VBV in a VBV Update module;

performing a potential underflow check in a Potential Underflow Check module;

after determination of the underflow potential level: increasing the virtual buffer-fullness in an Increase Virtual Buffer-Fullness module; and/or setting the panic mode coding in a Set Panic Mode Coding module; and

encoding a slice in an Encode a Slice module.

8. A method as claimed in any one of the claims 1 to 7 wherein, the method assists in panic mode coding prevention by addition of a preventive margin to a target bits factor T.

9. A method as claimed in any one of the claims 1 to 8 wherein, a variable panic level may be used.

10. A method as claimed in any one of the claims 1 to 9 wherein, for constant bit-rate coding:

at the picture level:

overflow prediction is rendered more sensitive by incorporating a factor dependent on the encoding bit-rate; and

reducing the virtual buffer-fullness when a factor *extra-bits* is greater than 0;

at the slice level:

estimating the VBV buffer-fullness in each slice and reducing the virtual buffer-fullness if required.

11. A method as claimed in any one of the claims 1 to 10 wherein, specified levels of buffer-fullness are experimentally determined for each picture type.

12. A method as claimed in claim 11 wherein, values of *Th1, Th2 and Th3* are 200 000, 150 000 and 100 000 respectively for a PAL picture.

13. Apparatus for Video Buffer Verifier (VBV) control of a video encoder, whereby the apparatus contains integrated picture and/or slice level controls, said picture and/or slice level controls including:

a virtual buffer-fullness control for increasing the sensitivity of a Q-step; and/or

a quantization-step range control for increasing the range of the Q-step.

14. Apparatus as claimed in claim 13 wherein, the apparatus additionally includes quantization matrices modification for the prevention of panic mode coding.

15. Apparatus as claimed in either claim 13 or claim 14 wherein, at the picture level said apparatus includes:

at least one VBV Update module;

at least one Potential Overflow Check module;

a Decrease Virtual Buffer Fullness and Increase Bit Allocation module;

a Decrease Bit Allocation module;

an Increase Quantization Range module; and

a Modify Q-Matrices and Decrease Virtual Buffer-Fullness module;

and at the slice level said apparatus includes:

a VBV Estimation module;

a VBV Update module;

a Potential Overflow Check module;

a Potential Underflow Check module;

a Decrease Virtual Buffer-Fullness module;

an Increase Virtual Buffer-Fullness module;

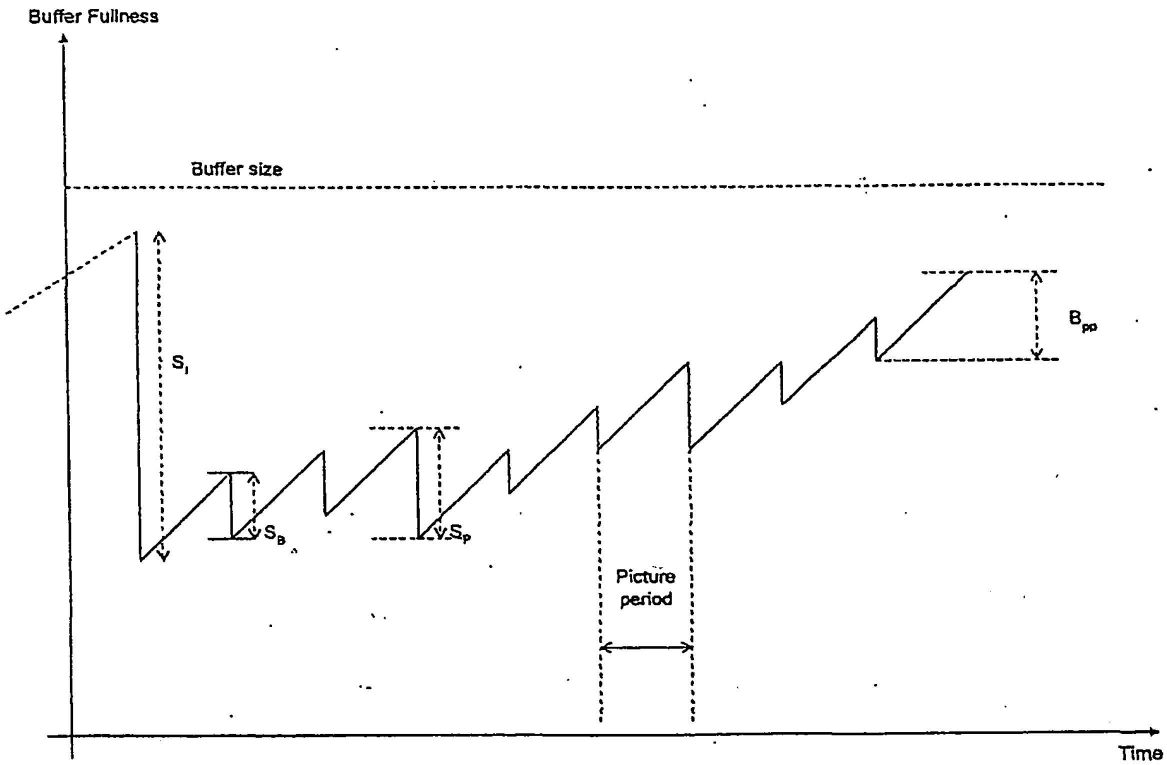
a Set Panic Mode Coding module; and

an Encode a Slice module.

16. A method for Video Buffer Verifier (VBV) control of a video encoder, substantially according to the method described in the specification with reference to the accompanying figures.

17. An apparatus for Video Buffer Verifier (VBV) control of a video encoder, substantially according to the embodiment described in the specification with reference to and as illustrated in the accompanying figures.

Figure 1


Buffer Fullness
Buffer size
S_I
S_B
S_P
B_pp
Picture period
Time

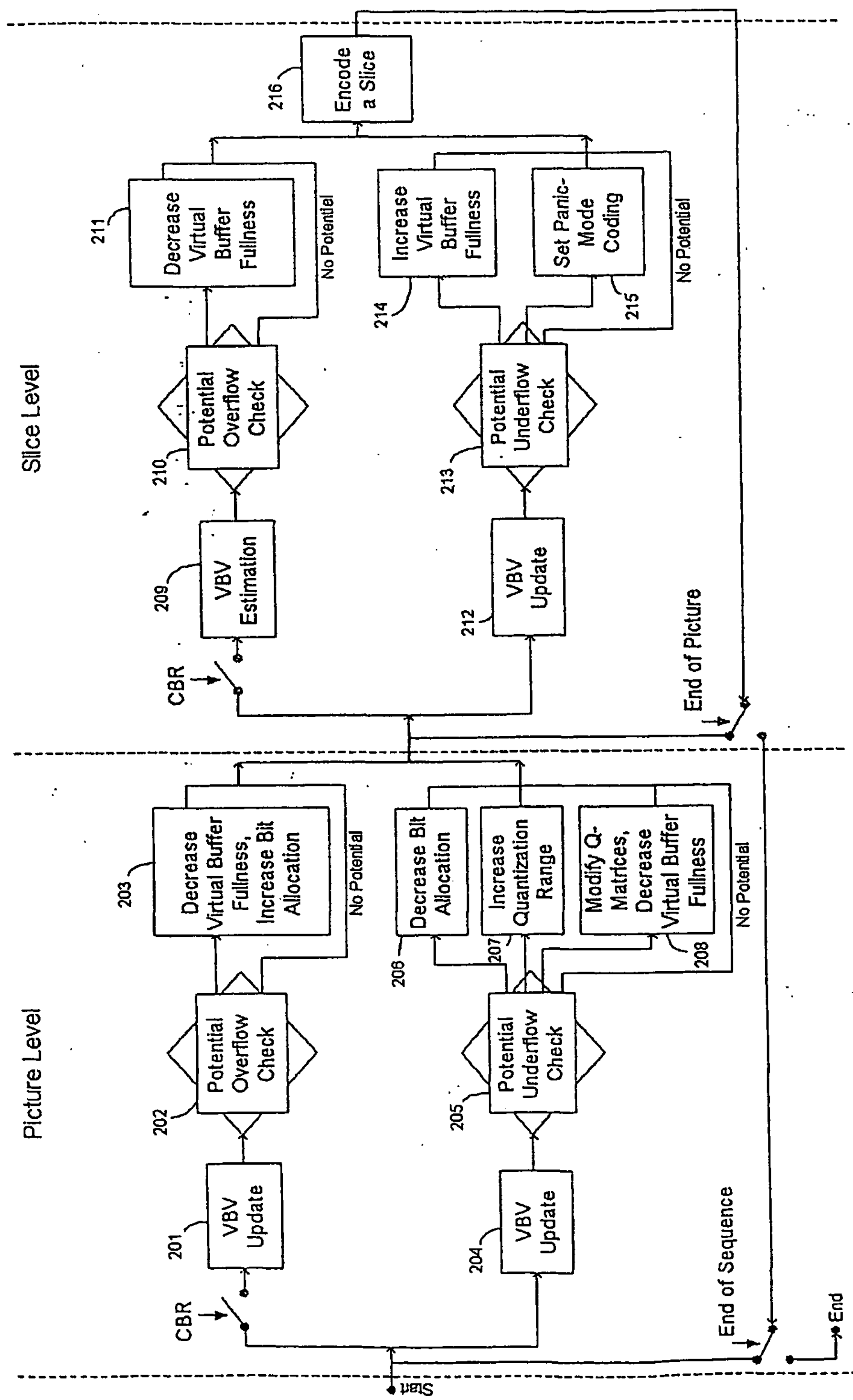

Picture Level
Slice Level
Start
CBR
201
VBV Update
202
Potential Overflow Check
203
Decrease Virtual Buffer Fullness, Increase Bit Allocation
No Potential
204
VBV Update
205
Potential Underflow Check
206
Decrease Bit Allocation
207
Increase Quantization Range
208
Modify Q-Matrices, Decrease Virtual Buffer Fullness
No Potential
End of Sequence
End
CBR
209
VBV Estimation
210
Potential Overflow Check
211
Decrease Virtual Buffer Fullness
No Potential
212
VBV Update
213
Potential Underflow Check
214
Increase Virtual Buffer Fullness
215
Set Panic-Mode Coding
No Potential
216
Encode a Slice
End of Picture

Figure 2

Figure 3

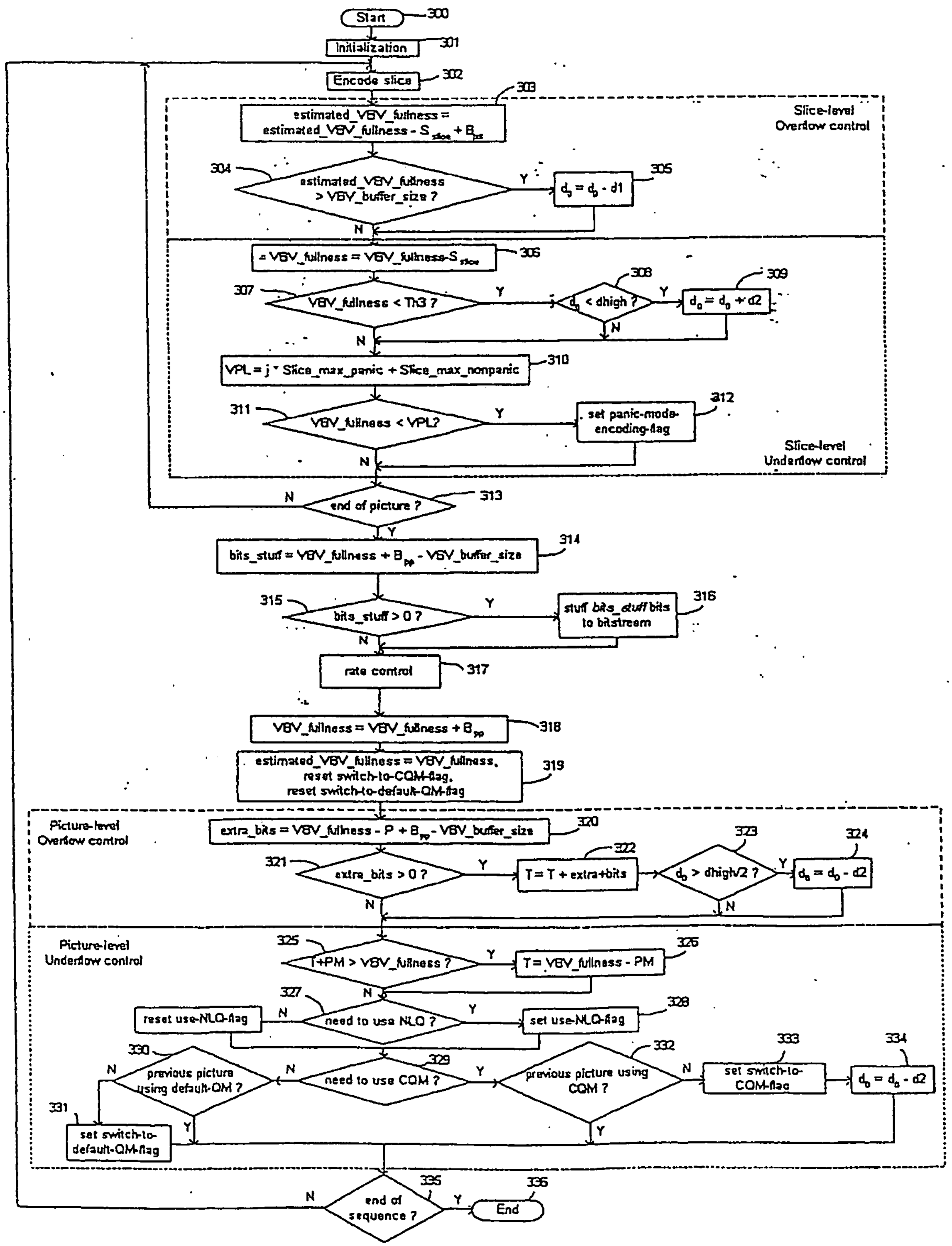


Figure 3

SUBSTITUTE SHEET (RULE 26)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/SG 01/00019

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N7/50

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 986 712 A (JONSSON RAGNAR HLYNUR ET AL) 16 November 1999 (1999-11-16)	1,3-6,13
A	column 3, line 37 -column 11, line 54	2,7, 10-12, 14,15
X	EP 0 928 111 A (SAMSUNG ELECTRONICS CO LTD) 7 July 1999 (1999-07-07)	1,3,5,6, 13
A	paragraph '0052! - paragraph '0060!	4,7,15
A	EP 0 836 329 A (SONY CORP) 15 April 1998 (1998-04-15) page 11, column 19, line 12 -column 20, line 2	1-15
A	US 5 801 779 A (WELLS AARON ET AL) 1 September 1998 (1998-09-01) column 14, line 32 -column 16, line 14	1-15

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 September 2001	18/09/2001

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/SG 01/00019

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